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Morphometric Analysis of Drainage Basin with Geographic Information Systems (GIS): A Case Study of Porsuk Stream Basin Eskisehir, Western Anatolia, Türkiye

Coğrafi Bilgi Sistemleri (CBS) ile Porsuk Çayı (Eskişehir) Havzasının Morfometrik Analizi

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ÖZET

Morfometrik parametreler kullanılarak gerçekleştirilen morfometri analizleri arazi ve yeryüzü şekillerinin biçimsel ve boyutsal ölçülerinin matematiksel olarak bir ifadesidir. Coğrafi Bilgi Sistemleri (CBS) kullanılarak gerçekleştirilen morfometri analizi havza karakterizasyon çalışmalarında yaygın olarak kullanılan pratik ve uygulanabilir bir yöntemdir. Sunulan çalışmanın amacı Sakarya Havzası'nın alt havzalarından biri olan Porsuk Çayı Havzası'nın morfometrik özelliklerinin Coğrafi Bilgi Sistemleri (CBS) kullanılarak incelenmesidir. Çalışmada 30 m çözünürlüklü Shuttle Radar Topography Mission (SRTM) Sayısal Yükseklik Modeli (SYM) verileri kullanılmıştır. Çalışmalara altlık oluşturacak SYM verileri üzerinden ArcGIS 10.8 yazılımı ile havzanın rölyef, alansal ve çizgisel morfometrik özellikleri incelenmiştir. Havzada çatallanma oranı, akarsu uzunluk oranı, akarsu sıklığı, drenaj yoğunluğu, gravelius indeksi, drenaj tekstürü, havza rölyefi, engebelilik değeri, hipsometrik eğri ve hipsometrik integral gibi morfometrik parametreler hesaplanmış, yükseklik, eğim, bakı ve arazi kullanım analizleri gerçekleştirilmiş ve alanın morfolojisini yansıtan tematik haritalar oluşturulmuştur. Çalışmadan elde edilen bulgular havza morfometrisini karakterize edecek bilgiler içermekte olup gelecekte bölgede farklı konularda yapılacak havza yönetim ve planlama çalışmalarına altlık oluşturacak veriler sunmaktadır.

Anahtar Kelimeler: Coğrafi Bilgi Sistemleri, Morfometrik Analiz, Porsuk Çayı Havzası, Sayısal Yükselti Modeli, Eskişehir

ABSTRACT

It is a mathematical expression of the formal and dimensional measurements of terrain and landforms using morphometric indices. Morphometry analysis performed using Geographic Information Systems (GIS) is a practical and applicable technique widely used in watershed characterization studies. The objective of the present study is to analyze the morphometric characteristics of the Porsuk Stream Basin, one of the sub basins of the Sakarya Basin, by using Geographic Information Systems (GIS). Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data with 30 m resolution were used in the study. Relief, areal and linear morphometric features of the basin were analyzed with ArcGIS 10.8 software over DEM data that will form the basis for the studies. Morphometric parameters such as as bifurcation ratio, stream length ratio, stream frequency, drainage density, gravelius index, drainage texture, basin relief, ruggedness number, hypsometric curve and hypsometric integral were calculated in the basin, elevation, slope, aspect and land use analyses were performed and thematic maps reflecting the morphology of the area were created. The findings obtained from the study contain information to characterize the basin morphometry and provide data that will form the basis for basin management and planning studies to be carried out in different subjects in the region in the future.

Keywords: Geographic Information Systems, Morphometric Analysis, Porsuk Stream Basin, Digital Elevation Model, Eskisehir

Introduction

Morphometry is a discipline that mathematically and geometrically measures and analyzes landforms in a river basin (Agarwal, 1998). Understanding the hydrological and morphological features of any region can be achieved by using morphometric parameters in morphological analyses (Joy et al., 2023; Bogale, 2021). In particular, determining the impact of geomorphological processes occurring in the basin on basin hydrology requires a detailed analysis of basin geometry (Mani et al, 2022). Morphometric analyses can provide information on the geometry, size and shape of basins as well as the characteristics of basin flow patterns (Patel et al, 2015). It is possible to understand hydrological processes, predict flow patterns, and identify areas susceptible to flooding and erosion (Rai et al, 2017; Farhan et al, 2017; Biswas et al, 1999). In this regard, morphometric analyses performed at the basin scale allow for a more detailed characterization of basins (Joy et al, 2023; Arabameri et al, 2020). It can also provide guidance on the formation and evolution of land surface processes (Waikar et al, 2014).

Morphometric studies for hydrological characterization in geomorphology were first initiated by Horton in 1932 (Horton, 1932). The study of Horton (Horton, 1945; 1932) on the morphometric properties of stream networks was developed by Strahler. Strahler, who defined the hypsometric curve parameter in 1952, defined the bifurcation ratio parameter obtained by calculating stream orders in 1964 (Strahler, 1964; 1952). Horton and Strahler's studies on stream morphometry have been developed by various scientists (Patel, 1988; Faniran, 1968; Chorley et al, 1957; Schumm, 1956; Miller, 1953) and have taken their place in the literature as applicable methods in morphometric studies.

In recent years, morphometric analyses in hydrological studies have been carried out at the basin scale (Joy et al, 2023; Bogale 2021; Pande and Moharir, 2017). In particular, morphometric parameters analyzed before starting basin-scale surveys and planning studies provide us with preliminary information about the topography, hydrology and geology of the region (Rai et al, 2017). In studies, morphometric parameters, which are an essential component of hydrological research, are widely used as a basis for research on water resources development and planning and the development of watershed management strategies (Mani et al, 2022; Bogale 2021; Arabameri et al, 2020).

Geographic Information System (GIS) techniques in particular have emerged as powerful technological tools for assessing various aspects of the current climate, structural features, geomorphology, hydrology and geology of watersheds (Wakode et al, 2013; Singh et al, 2013; Chopra et al, 2005). Nowadays, GIS technologies make it easier and more accurate to evaluate various terrain and morphometric parameters of river basins than in the past (Joy et al, 2023). In particular, GIS technology has been found to be an effective and widely used technique in basin-scale morphometric analysis (Joy et al, 2023; Bogale 2021). GIS applications provide a powerful interface for processing large databases in morphometric analysis, enabling the management of large datasets and the solution of many complex problems (Bogale et al, 2021; Mangan et al, 2019).

In the literature, there are various studies conducted to determine different morphometric characteristics of river basins using GIS technologies (Joy et al, 2023; Ege and Avsever, 2022; Mani et al, 2022; Bogale, 2021; Altıparmak and Türkoğlu, 2018; Elbaşı, 2015). The studies include morphometric analyses performed on digital elevation models of different resolutions using GIS (Sreedevi et al, 2009; Srinivasa Vittala et al, 2004). Morphometric analyses in GIS environment have been found to be very guiding in basin characterization studies (Joy et al, 2023; Mani et al, 2022; Bogale 2021; Arabameri et al, 2020).

It is seen that bifurcation ratio, stream density, drainage density, drainage texture, hypsometric curve and hypsometric integral parameters are frequently used in morphometric analyses (Joy et al, 2023; Bogale 2021; Arabameri et al, 2020; Pande and Moharir, 2017; Rai et al, 2017). However, it has been determined that the parameters used in morphometry analysis may vary according to the ongoing geomorphological processes in the basin (Farhan et al, 2017; Nooka Ratnam et al, 2005; Biswas et al, 1999).

Limited studies in various disciplines (Yıldıran and Kandemir, 2020; Faize, 2016; Tekkanat, 2015) are available in the literature on the Porsuk Stream Basin, which was determined as the study area. The aim of the present study is to evaluate the morphometric characteristics of the Porsuk Stream Basin with the help of morphometric parameters in GIS environment and to examine the geomorphological processes developing in the basin. Additionally, it is essential to investigate the factors that may be effective in any flood disaster or erosional processes that may occur on the Porsuk Stream due to changing climatic conditions and anthropogenic effects depending on the areal, relief and linear morphometry of the basin. Therefore, it is thought that the morphometric analyzes carried out in the Porsuk Stream Basin, which is the subject of the study, can provide data that will form the basis for basin survey and planning studies to be carried out in soil, water, flood, erosion etc. disciplines.

Materıals and Methods

Study Area

The Porsuk Stream Basin, which was determined as the study area, is located in the northwestern part of the Central Anatolia Region of Turkey, east of Kütahya province and Eskişehir province borders. Porsuk Stream, the longest tributary of the Sakarya River, flows in the east-west direction within the Eskişehir plain. The catchment area, which is 357.50 km long and is joined by tributaries from the north and south, is located between 29° 36' and 31° 57' east longitude and 38° 43' and 39° 97' north latitude. Porsuk Stream Basin with 925.65 km of perimeter has a mean elevation of 1052 m above sea level. The Porsuk Stream basin is one of the sub-basins of the Sakarya Basin and is surrounded by the Sündiken Mountains (1770 m) to the north, the Türkmen Mountain (1826 m) to the south, the Sivrihisar Mountains (1819 m) and the Elmalı Mountain (1512 m) to the southeast, and the Sakarya River to the east. Alpu, Mihalıççık, İnönü, Beylikahır and Tepebaşı districts, which are located within the Porsuk Stream basin where the elevation varies between 667 m and 2062 m, are the important settlements of the study area (Figure 1). As the basin is located in the inner part of Western Anatolia, temperate continental climate characteristics prevail in the study area.

The Porsuk Stream Basin, which was selected as the study area, generally has a gently sloping topography. While the amount of slope in the basin varies between 0 and 58°, the mean slope value of the basin is 5.6°. The proportion of areas with a slope between 0 and 3° is 35.8%. Areas with a slope of 30° and above occupy 0.1% of the area.

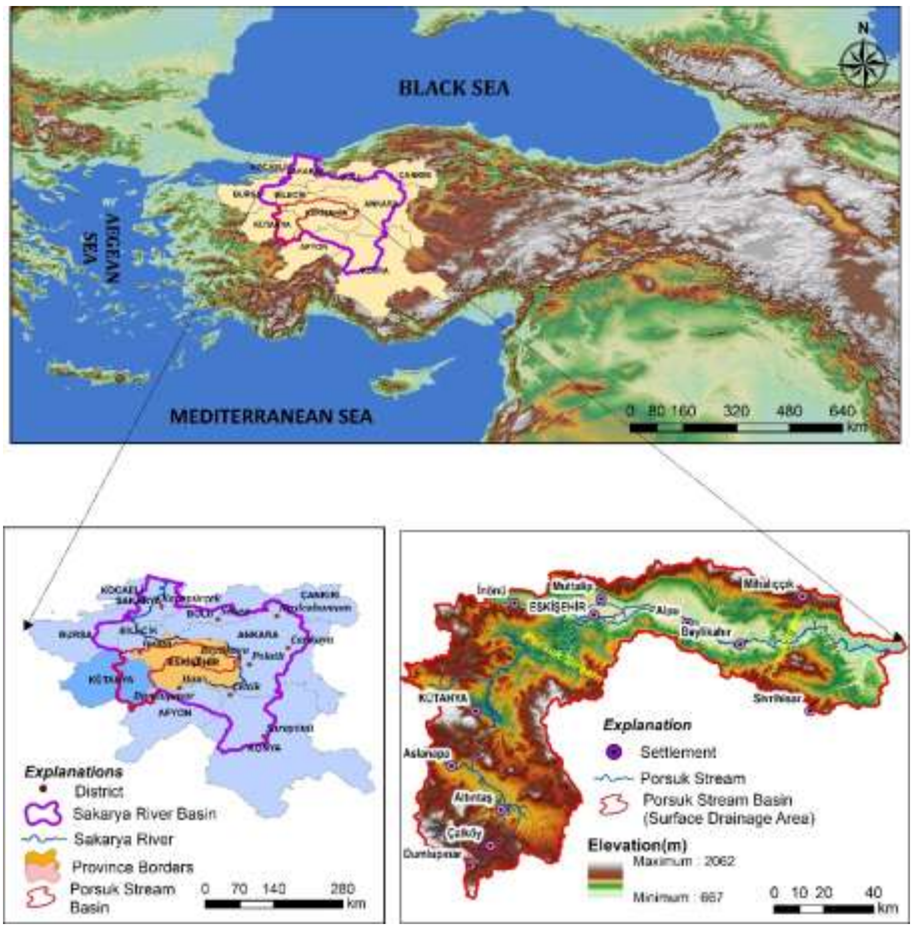

Figure 1. Location Map of Study Area

In terms of the slopes of the basin, north-facing slopes occupy 38.86%, south-facing slopes occupy 41.14%, east-facing slopes occupy 10.49%, and west-facing slopes occupy 9.52%. It was determined that the proportion of south-facing slopes was higher throughout the basin. Land use/land cover classes in the study area were analysed with European Environment Agency (EEA) Coordination of Environmental Information (CORINE) data (European Environment Agency, 2024). When the land cover classes are evaluated, it is seen that artificial areas cover an area of 313.20 km^2, agricultural areas 5547.33 km^2, forest and semi-natural areas 4883.71 km^2, wetlands 3.72 km^2, and water bodies 39.29 km^2 (Figure 2).

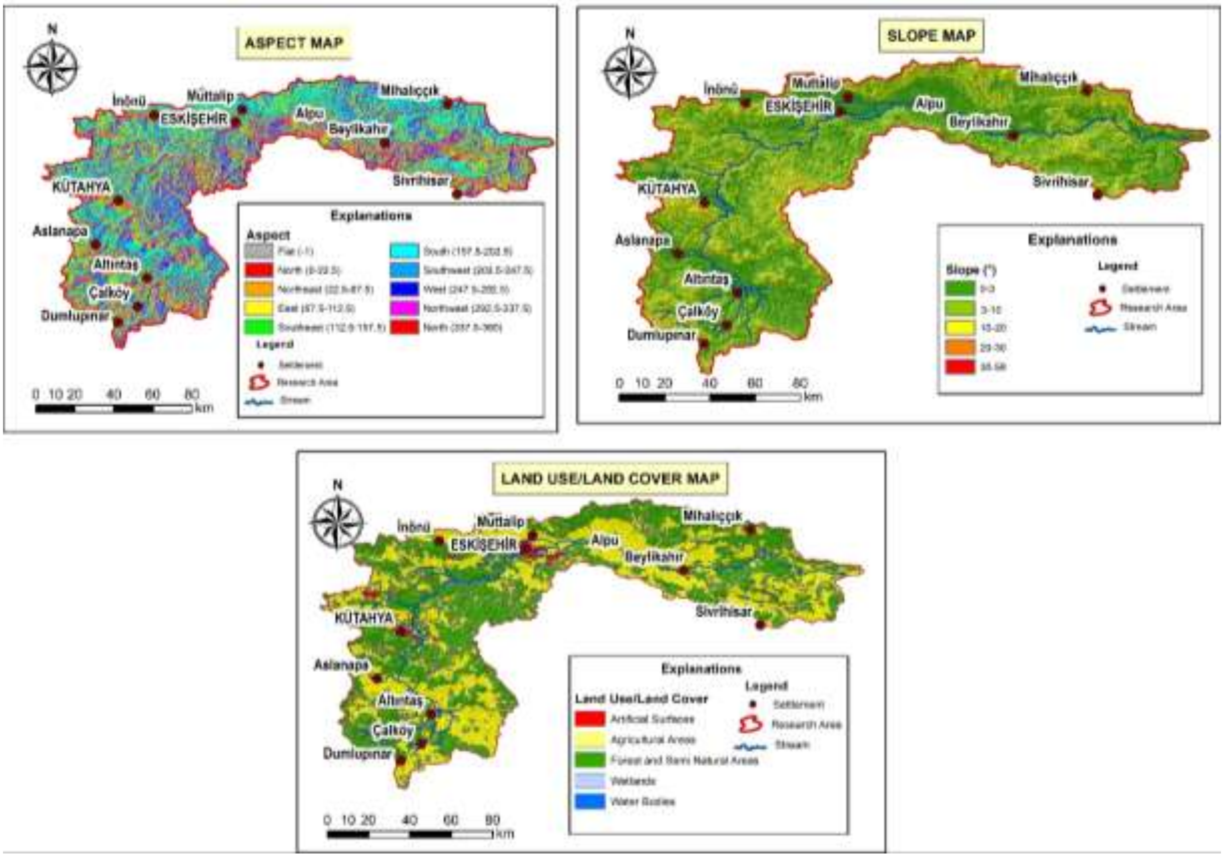

Figure 2. Slope, Aspect and Land Use/Land Cover Maps of Study Area

Method

The morphometric characteristics of the Porsuk Stream Basin were determined using Digital Elevation Model (DEM). The DEM produced for the study area was used as the base data for the analysis. It has been noted that the results of the morphometric analysis of the river basins using the DEM analysis accurately depict the natural drainage morphometry. Accordingly, SRTM (Shuttle Radar Topography Mission) data with a resolution of 30 m downloaded from the United States Geological Survey (USGS) portal were used in the study area (USGS, 2024). Using the mosaicking command in the ArcGIS 10.8 software, 10 separate images covering the study area were combined to create the basin's DEM (Digital Elevation Model). The Universal Transversal Mercator (UTM) World Geodetic System 1984 (WGS 84) Zone 36 projection system was used to create all of the study's data. By eliminating the errors in different hump and pit areas within the study area's boundaries, a new, improved DEM was created using the DEM obtained following the mosaicking of the images. The enhanced DEM produced with the fill command of the ArcGIS interface was used to extract the river drainage network and the boundary of the watershed surface drainage area. The basin drainage area boundary was finalized by checking from 1/100.000 scale topographic maps. Basin hydrological analysis was performed with the help of various commands of the hydrology module of the ArcGIS interface (Figure 3). The hydrological basin analysis was performed using the D8 method, which is defined as an eight-major directional flow model developed by Jenson and Domingue (1988). The natural river flow directions and river network in the basin were extracted. According to the Strahler (1964) approach, stream orders, number of orders and stream lengths were determined. In the creation of the river network, an appropriate threshold value of 60.000 pixels was used to appropriately represent the river drainage network in the DEM.

Linear (1-dimensional), areal (2-dimensional) and relief (3-dimensional) morphometric analyses were carried out in the study area, Porsuk Stream Basin. Morphometric parameters were calculated with the help of these analyses and various empirical equations used in basin characterization. The morphometric characterization of the Porsuk Stream Basin was evaluated with the numerical data obtained. A flowchart summarizing the study methodology is presented in Figure 3 and all formulas used to calculate the morphometric parameters used in the study are presented in Table 1.

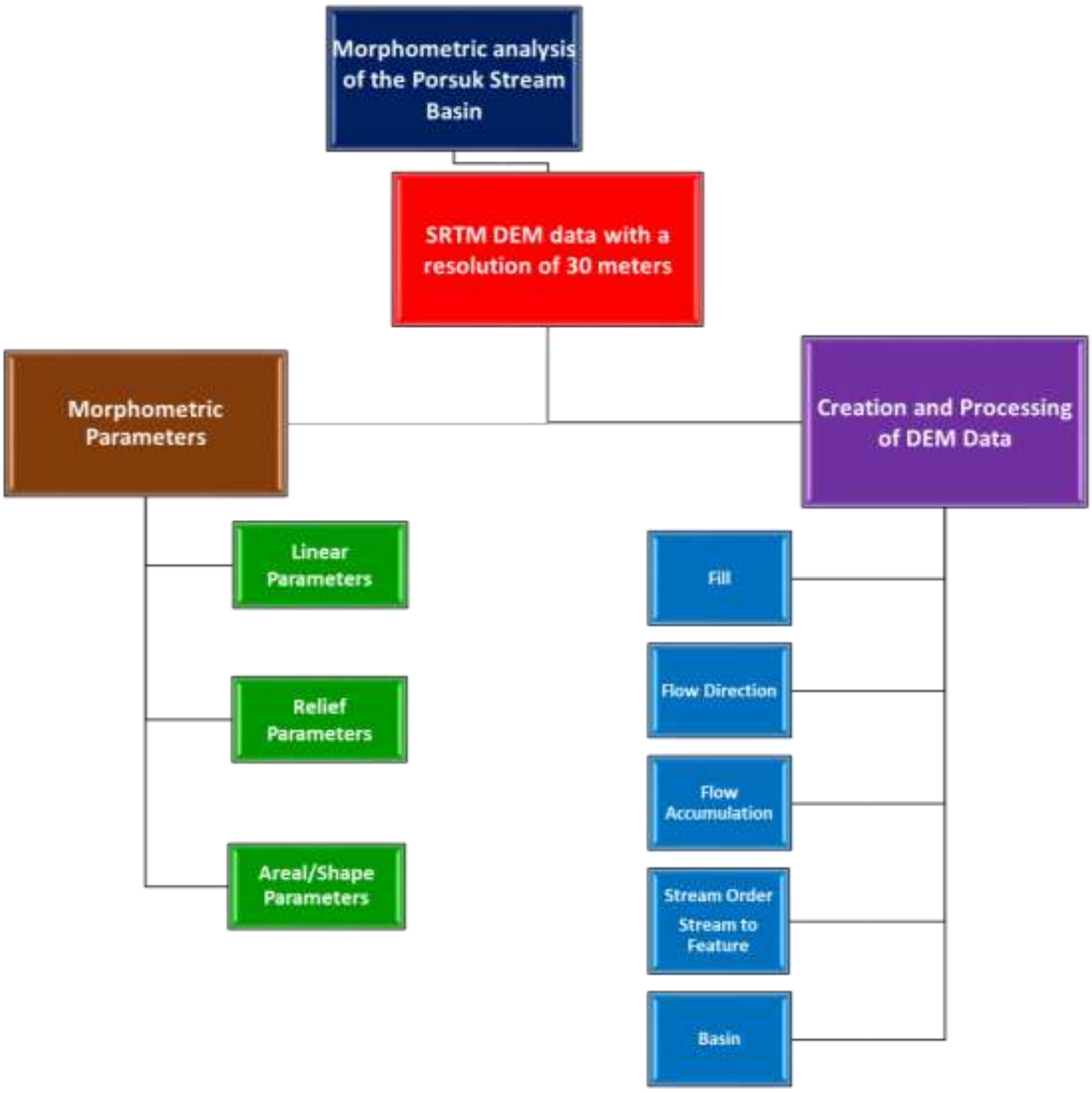

Figure 3. Basin Morphometric Analysis Workflow Chart

Table 1. Parameters, Formulas and Methods Used in Morphometric Analysis of Porsuk Stream Basin

Morphometric Parameters/Symbol	**Formula/Method**	**Unit**	**Reference**
Basin Linear Parameters			
Stream Order (U)	Hierarchical Rank	Dimensionless	Strahler (1964)
Stream Length (Lu)	$Lu=Lu_1+Lu_2+Lu_3\cdots+Lun$	Kilometer (km)	Horton (1945)
Stream Number (Nu)	$Nu=Nu_1+Nu_2+Nu_3\cdots+Nun$	Dimensionless	Horton (1945)
Stream Length Ratio (R_L)	$R_L=Lu/Lu-1$	Dimensionless	Horton (1945)
Mean Stream Length (Lsm)	$L_{sm}=Lu/Nu$	Kilometer (km)	Strahler (1964)
Bifurcation Ratio (Rb)	$Rb=Nu/Nu+1$	Dimensionless	Schumm (1956)
Stream Frequency (Fs)	$Fs=(\sum Nu)/A$	km^{-2}	Horton (1945)
Drainage Density (Dd)	$Dd=(\sum Lu)/A$	km/km^2	Horton (1932)
Drainage Texture (Dt)	$Dt=(\sum Nu)/P$	km^{-1}	Horton (1945)
Basin Areal Parameters			
Basin Area (A)	Analysis in ArcGIS Software	km^2	
Basin Perimeter (P)	Analysis in ArcGIS Software	Kilometer (km)	
Basin Length (Lb)	Lb= 1.312 ×A0.568	Kilometer (km)	Nookaratnam et al (2005)
Form Factor (Ff)	$Ff=(A/Lb^2)$	Dimensionless	Horton (1932)
Gravelius Index (Kg)	$Kg=P/2\sqrt{\pi * A}$	Dimensionless	Gravelius (1914)
Maximum Basin Width (W)	Analysis in ArcGIS Software	Kilometer (km)	
Basin Relief Parameters			
Maximum Elevation (H_{max})	Analysis in ArcGIS Software	Meter (m)	
Minimum Elevation (H_{min})	Analysis in ArcGIS Software	Meter (m)	
Basin Relief (Bh)	$Bh=H_{max}-H_{min}$	Kilometer (km)	Schumm (1956)
Relief Ratio (Rh)	$Rh=B_h/L_b$	Dimensionless	Schumm (1956)
Ruggedness Number (Rn)	$Rn=B_h \times D_d$	Dimensionless	Strahler (1957)
Hypsometric Curve	X=a/A, Y=h/H		Strahler (1952)
Hipsometric Integral	$H_{ort}-H_{min}/H_{max}-H_{min}$	Dimensionless	Strahler (1952)
Slope (°) Analysis	Analysis in ArcGIS Software		
Aspect Analysis	Analysis in ArcGIS Software		

Findings

Morphometric analyses were carried out by calculating the DEM created for the Porsuk Stream Basin and the elevation, slope, slope exposure, raster data derived from this data set and the linear, areal and relief parameters using GIS technology. In the analyses performed, the morphometric parameters of the Porsuk Stream Basin were mathematically calculated with the help of various empirical equations.

Linear Morphometry Parameters

Linear morphometry is defined as the shape features that first stand out in a basin. The number of stream orders, number of streams in each order, bifurcation ratio, stream frequency, main stream length, drainage texture, drainage density, and stream length ratio were the parameters used to analyze the linear morphometry in the study area.

Stream Order (U) and Stream Number (Nu)

In the study area, the calculations of the stream orders were calculated by considering the method proposed by Strahler (1964). The Porsuk Stream Basin was divided into four order using the Strahler (1964) approach, and it was determined that each stream segments in each order included a total of 147 tributaries (Figure 4). A total of 147 tributaries were present in the basin of which 74 belong to 1st order, 31 to 2nd order, 27 to 3rd order and 15 are 4th order.

Main Stream Length (L)

The length of Porsuk Stream, which is the main continuous stream in the Porsuk Stream Basin, is determined as 357.50 km. The length of the main stream was calculated by including the length from the beginning of the fourth stream order to the end of the third stream order, which is created according to the Strahler (1964) system of stream ordering (Figure 4).

Mean Stream Length (Lsm)

The mean stream length represents a measurable feature of the drainage system and the adjacent surfaces (Strahler, 1964). The total lengths of all the streams in each order were summed up and then divided by the number of streams in that order. It is a dimensionless morphometric parameter and denoted by Lsm. The mean stream length of the Porsuk Stream Basin is 8.29.

Stream Length (Lu)

The sum of the length of streams in a given order is the total stream length of that order and the sum of the lengths of all the streams is the total stream length of the basin (Horton, 1945). Generally, the overall length of stream segments is greatest in first-order streams and diminishes as the stream order ascends. (Horton, 1945). It is a crucial parameter used in hydrology to describe the characteristics of a stream network and it is denoted by Lu. 1st order streams demonstrate the greatest stream length, measuring 729.1 km in the basin (Table 2). The discrepancies in stream length observed between the 2nd and 3rd order suggest that both lithological and morphological factors exert influence over the basin area. The total stream length of the Porsuk Stream Basin is 1293.3 km.

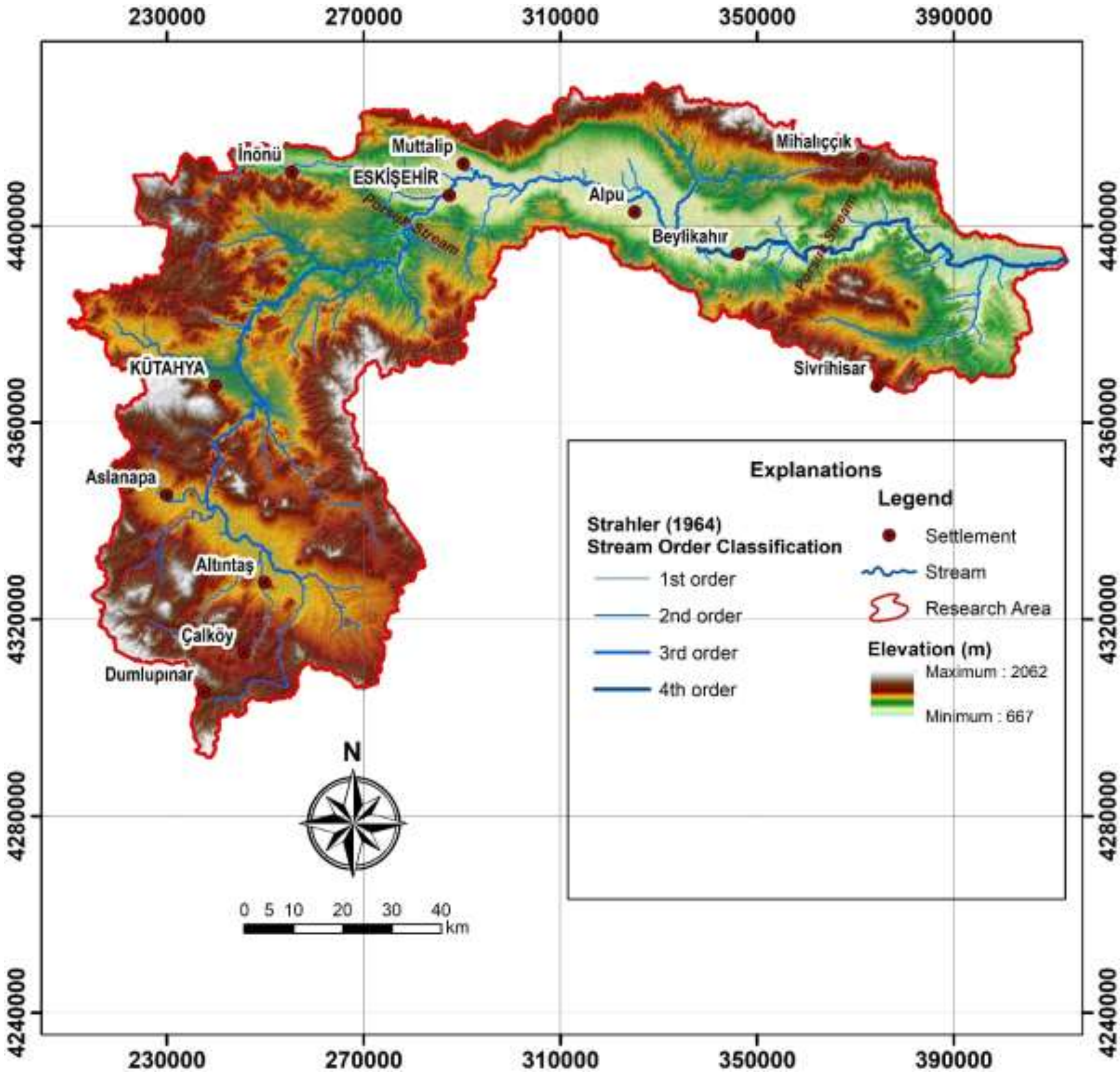

Figure 4. Stream Orders of the Porsuk Stream Basin According to Strahler (1964) Method

Bifurcation Ratio (Rb)

The bifurcation ratio (Rb) value is calculated as the ratio of the number of tributaries (Nu) in a given order in a river basin to the number of tributaries (Nu+1) in the next higher order (Strahler, 1964). The average of the bifurcation ratios calculated across all indices gives the catchment bifurcation ratios (Rai et al, 2018). It is stated that in basins where the bifurcation ratio value, which is a dimensionless parameter, is low, the effect of geological processes on river drainage is very low, while in basins where the value is high, geological processes are dominant on the river drainage network (Strahler, 1964). It is stated that the geological structure of the basins with a bifurcation ratio between 3 and 5 is more homogeneous (Verstappen, 1983). It has been reported that in basins with low Rb values, the peaks of flow hydrographs show high and sharp curves, while in basins with high Rb values, the peaks of hydrographs are seen as diffuse and continuous curves (Agarwal, 1998). Basin bifurcation ratio in the study area was calculated as 1.78 (Table 2). The low bifurcation ratio value calculated for the basin suggests that flood characterized flows may occur as a result of sudden precipitation in the basin.

Stream Length Ratio (R_L)

The stream length ratio (R_L) is calculated as the ratio of the total length (Lu) of the tributaries in a given order in the basin to the total number of tributaries in the next order (Lu+1) (Patton, 1988). The average of the stream length ratios calculated between the stream orders gives the basin stream length ratio (Patton, 1988). When the basin shape is longitudinal, the mean values and sum of the stream order length ratios are less than in circular basins (Patton, 1988). In circular basins, accumulation and retention in the main river tributary, and consequently susceptibility to flooding and inundation, is higher than in longitudinal basins (Patton, 1988). The stream length ratio for the study area was calculated as 2.17 (Table 2). The fact that the R_L value calculated for the basin is not high indicates a narrow and longitudinal basin where the stream is easily drained.

Table 2. Calculated Values for Linear Morphometry Parameters in the Porsuk Stream Basin

Stream Order Number	Stream Number (Nu)	Bifurcation Ratio (Rb)	Stream Length (Lu) (km)	Mean Stream Length (Lsm)(km)	Stream Length Ratio (R_L)	Drainage Density (Dd)	Stream Frequency (Fs)	Drainage Texture (Dt)
1	74		729.1	9.85		0.12	0.01	0.16
2	31	2.39	206.8	6.67	3.53			
3	27	1.15	243.0	9.00	0.85			
4	15	1.80	114.5	7.63	2.12			
	Total:147	**Mean:1.78**	**Total:1293.3**	**Mean: 8.29**	**Mean: 2.17**	**0.12**	**0.01**	**0.16**

Drainage Texture (Dt)

Drainage texture (Dt) is calculated as the ratio of the sum of the number of streams for all orders of the hierarchical river network for the basin according to the Strahler method to the basin perimeter length (Reddy et al, 2004). Basin texture value varies according to surface permeability, basin geology and aspect factors. The low texture value indicates that the number of 1st order tributaries connected to the main tributary is low. A high texture value indicates a high number of 1st order tributaries joining the main river (Reddy et al, 2004). As the drainage texture value increases, the basin shape changes from elongated to rounded (Özdemir, 2011). In the Porsuk Stream Basin, the Dt value was calculated as 0.16 (Table 2). This calculated value indicates that the basin has a longitudinal form.

Drainage Density (Dd)

Drainage density (Dd) is defined as the mean stream length per unit area and is calculated by dividing the total length of the stream by the catchment area (Horton, 1932). High values of drainage density corresponding to stream length per unit area in the basins indicate impermeable soil, sparse vegetation, high relief, high surface runoff and low infiltration capacity (Horton, 1932; Horton, 1945). The low drainage density value is characterized by permeable lithology, dense vegetation, low relief, low slope, slow surface runoff and high infiltration capacity (Özdemir, 2011). The drainage density value, which is an indicator of the level of land surface fragmentation by rivers, was calculated as 0.12 km/km^2 for the study area (Table 2). The low drainage density value calculated for the basin indicates the presence of permeable soil in the region and high infiltration capacity with low surface runoff.

Stream Frequency (Fs)

Stream frequency (Fs) is calculated as the ratio of the total number of streams in the basin to the basin area (Strahler, 1964). High Fs values in a basin indicate sparse vegetation, impermeable lithology and high relief, while low Fs values are characterized by dense vegetation, permeable lithology and low relief (Reddy et al, 2004). Fs value in the basin exhibits a direct relationship with the drainage density value of the area. This indicates that a reduction in drainage density is associated with a decline in the number of streams present within the basin. The stream frequency value for the study area was calculated as 0.01 (Table 2). The low Fs value of Porsuk Stream Basin is indicative of less relief, dense vegetation and low slope conditons.

Areal Morphometric Parameters

Spatial morphometry is very important in terms of collection and transmission of rainfall falling on the surface drainage area of the basin, drainage of the basin by rivers and determination of the flow relationship. Spatial morphometric analyses in the Porsuk Stream Basin were examined within the framework of basin area, basin perimeter, basin length and maximum basin width, form factor and gravelius index parameters.

Basin Area (A)

The catchment area is a very crucial parameter in morphometric analysis and is defined as the area where water is collected together with all the tributaries of the main river. Basin area is directly related to the volume of water collected in the basin and the flow pattern of the river. It is denoted by A. The surface drainage area of the Porsuk Stream Basin is calculated as 10.791 km^2 in the GIS environment (Table 3).

Basin Perimeter (P)

The boundary surrounding the catchment drainage area is defined as the catchment perimeter and is designated by P. Basin environment and basin shape are factors directly related to each other. The shorter the basin perimeter, the more circular the basin becomes, while as the perimeter length increases, the basin evolves into a longitudinal and narrow form. The basin perimeter of Porsuk Stream, which is the study area, was calculated as 925.65 km in the GIS environment (Table 3).

Basin Length (Lb)

Basin length (Lb) is calculated as the longest distance in the horizontal plane parallel to the main river flow line. The basin length of the study area was calculated as 202.26 km with ArcMap interface in GIS environment (Table 3).

Maximum Basin Width (W)

The maximum catchment width (W) is the distance measured perpendicular to the long axis of the catchment and determined to correspond to the widest boundary areas of the catchment. The maximum width of the Porsuk Stream Basin was measured as 137.29 km using ArcMap interface in GIS environment (Table 3).

Form Factor (Ff)

Form factor (Ff) is a parameter calculated by dividing the catchment surface area by the square of the catchment length (Horton, 1932). Low values of the form factor (<0.78) describe long and narrow basins, while high values (>0.78) describe relatively shorter, near-circular basins (Horton, 1932). In the Porsuk Stream Basin, the form factor was calculated as 0.26 (Table 3). A value less than 0.78 indicates a longitudinal basin shape with a long flow collection time and a basin length greater than the basin width.

Gravelius Index (Kg)

The gravelius index parameter (Kg) is a parameter calculated with the help of an empirical equation using the Gravelius (1914) approach where the basin perimeter length and basin area parameters are used. While basins with a Kg value approaching 1 show circular characteristics, it is stated that basins take a longitudinal shape with increasing Kg value (Patel et al, 2015). The gravelius index value for the study area was calculated as 2.51 (Table 3). The Kg value calculated for the study area indicates that the basin is a longitudinal basin and the erosion risk in the basin is low.

Table 3. Spatial Morphometry Parameters Calculated in the Porsuk Stream Basin

Basin Area (A-km^2)	Basin Perimeter (P-km)	Basin Length (Lb-km)	Maximum Basin Width (W-km)	Form Factor (Ff)	Gravelius Index (Kg)
10.791	925.65	202.26	137.29	0.26	2.51

Basin Relief Parameters

Three-dimensional topographic features were evaluated within the scope of relief morphometry analysis in the Porsuk Stream Basin. In this framework, firstly, elevation, slope and aspect analyses were carried out in the study area. Hypsometric integral and hypsometric curve, ruggedness number, basin relief and relief ratio parameters were evaluated according to elevation groups.

Roughness Number (Rn)

Basin roughness number (Rn) is calculated by multiplying drainage density and basin relief (Melton, 1957; Strahler, 1957; Schumm, 1956). The ruggedness number, which is a dimensionless parameter, indicates the structural complexity of the terrain together with relief and drainage density (Melton, 1957). Low ruggedness numbers in watersheds indicate that the terrain is low sloping and hilly, less erosion by streams, less time for water to remain on the surface, higher infiltration and less susceptible to soil erosion (Melton, 1957). The ruggedness number (Rn) for the Porsuk Stream Basin was calculated as 0.17 (Table 4).

Basin Relief (Bh)

According to the basin elevation groups, the difference between the highest point (Hmax) and the lowest point (Hmin) of the study area was defined as basin relief (Bh) according to Schumm (1956). According to the DEM, the highest point in the study area is 2062 m and the lowest elevation point is

667 m (Table 4).

According to these data, the basin relief of Porsuk Stream is calculated as 1395 m. It has been determined that the basin relief is low due to the high number of low slope areas in the study area, the low slope of the river beds and the fact that the slopes are not very steep except in limited areas.

Relief Ratio (Rh)

In the Schumm (1956) approach, the relief ratio is calculated as the ratio of basin relief (Bh) to the maximum basin length (Lb). Low relief indicates a topography with low slopes and low relief, while high relief indicates a topography with high relief and steep slopes. In particular, the relief ratio value and soil susceptibility to erosion are highly correlated with each other. The basin relief ratio was calculated as 0.01, which indicates a topography with low slope and a land with low erosion risk.

Table 4. Calculated Relief Morphometry Parameters in the Porsuk Stream Basin

Ruggedness Number (Rn)	Basin Relief (Bh) (m)	Relief Ratio (Rh)	H_{mean} (m)	H_{min} (m)	H_{max} (m)	Hypsometric Integral (Hi)
0.17	1395	0.01	1052	667	2062	0.28

Hypsometric Curve (Hc)

The hypsometric curve (Hc) shows the basin elevation distribution and areal distribution according to the elevation values in the DEM (Strahler, 1952). The height and area values in the hypsometric curve are generated as a function of the maximum height and total area of the basin. The hypsometric curve is obtained by comparing the ratio of the area above any elevation value (h) in the study area to the entire area (relative area) and the ratio of any elevation value to the maximum elevation value of the basin (relative elevation) in the two-dimensional Cartesian coordinate plane (Strahler, 1952). The hypsometric curve of the study area was classified under 10 elevation groups with the help of DEM (Table 5 and Figure 6). Areal and proportional distribution of elevation in the basin and relative area and relative elevation values were calculated (Table 5 and Table 6).

Table 5. Hipsometric Curve Components Calculated for the Study Area

Elevation (h)	Maximum Height (H)	Surface Area (a)	Basin Area (A)	Relative Height (h/H)	Relative Area (a/A)
667	2.062	10.791	10.791	0.32	1.00
813	2.062	9.457	10.791	0.39	0.88
898	2.062	8.266	10.791	0.44	0.77
984	2.062	6.878	10.791	0.48	0.64
1060	2.062	5.117	10.791	0.51	0.47
1131	2.062	3.444	10.791	0.55	0.32
1206	2.062	2.038	10.791	0.58	0.19
1295	2.062	1.046	10.791	0.63	0.10
1406	2.062	461	10.791	0.68	0.04
1552	2.062	127	10.791	0.75	0.01
2062	2.062	0	10.791	1.00	0.00

The hypsometric curve formed according to the relative area and relative elevation values in the Porsuk Stream Basin is concave (Figure 5). The concave shape of the hypsometric curve in the study area indicates that the river flow in the basin is not very fast, the sediments transported are less, the sedimentation process is dominant and generally the flood and flood hazard is low.

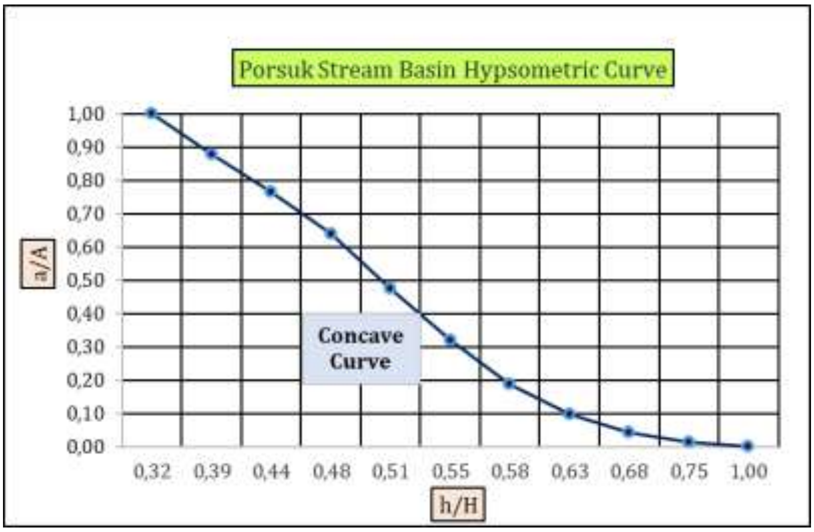

Figure 5. Hypsometric Curve for the Porsuk Stream Basin

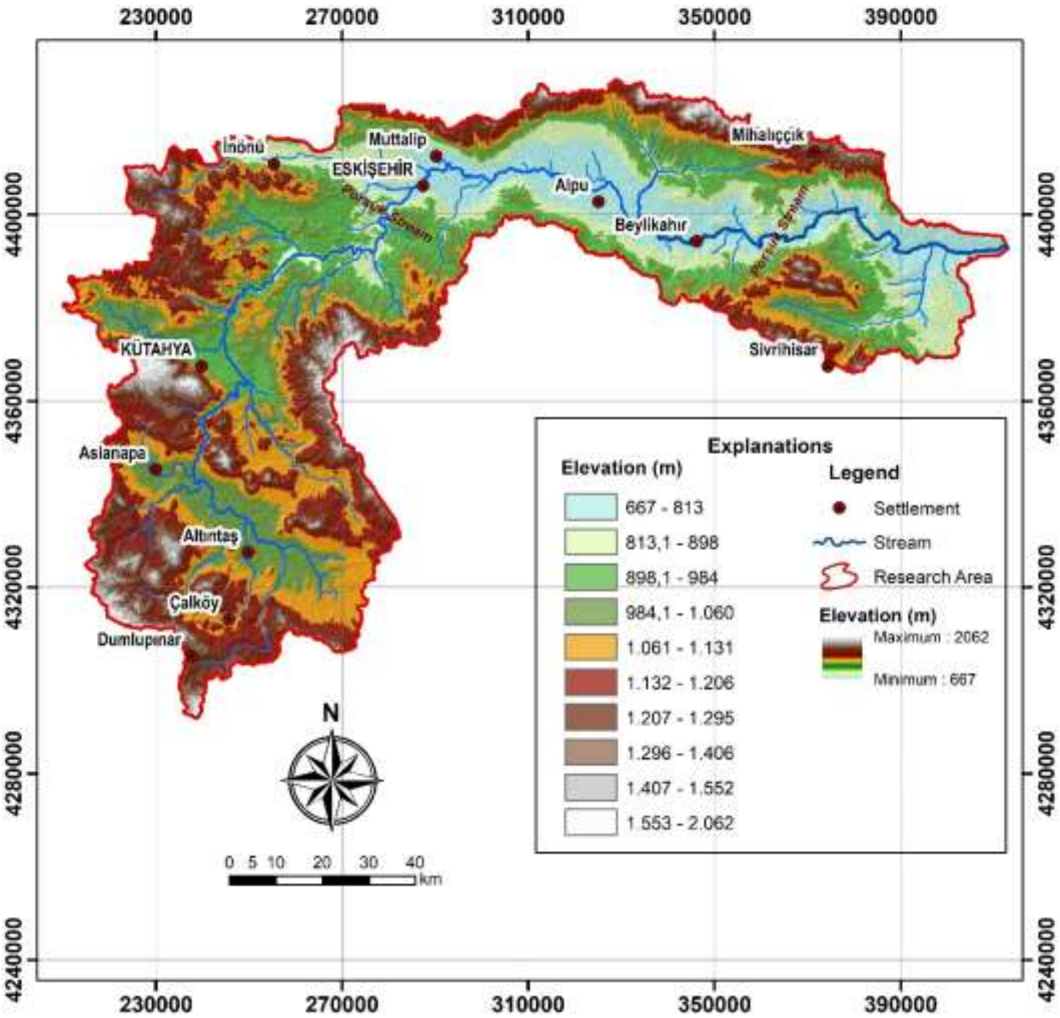

Figure 6. Elevation Distribution Map of the Study Area

Table 6. Spatial and Proportional Distribution of Elevation in the Study Area

Elevation Interval (m)	Area (km^2)	Percentage of the Area (%)
667-813	1334.02	12.40
813.1 - 898	1191.01	11.00
898.1 - 984	1387.52	12.90
984.1 - 1.060	1761.01	16.30
1.061 - 1.131	1673.11	15.50
1.132 - 1.206	1406.59	13.00
1.207 - 1.295	991.93	9.20
1.296 - 1.406	584.67	5.40
1.407 - 1.552	333.84	3.10
1.553 - 2.062	127.24	1.20
Total	**10.791**	**100**

Hipsometric Integral (Hi)

Hypsometric integral, one of the relief parameters, is defined by Strahler (1952) as the total area under the hypsometric curve. The Hi value for the study area was calculated using the minimum, mean and maximum elevation values of the basin. The hypsometric integral value, which provides information about the morphological development of a region, the degree of fragmentation of the topography, and the stage of the basin in the erosion cycle, varies between 0 and 1 (Mayer, 1990). According to the hypsometric integral value, basins are divided into three stages as old, mature and young (Özdemir, 2011). The hypsometric integral value is less than 0.3 in the old stage, between 0.3 and 0.6 in the mature stage and greater than 0.6 in the young stage (Özdemir; 2011). It has been reported that a landscape in the old age stage is less susceptible to erosional processes (Sharma and Mahajan, 2020).

The calculated hypsometric integral value for the study area is 0.28. The calculated integral value indicates that the basin has an old land surface with a high rate of fragmentation and erosion in terms of erosion stage. This stage is characterized by low slope of the main river bed in the basin, low river flow velocity and low sediment transport. In addition, it is observed that the valleys in the basin are considerably widened by the erosion of the lateral river tributaries, tectonic activity has stabilized and it is represented by a flat topography with smoother transitions between surface forms.

Conclusions and Recommendations

Morphometric parameters are represented by empirical equations that can be quantitatively measured and used to understand the hydrological and morphological characteristics of any watershed. In particular, the hydrological behavior of catchments is reflected by certain morphometric characteristics of the catchment. In recent years, GIS technologies have been widely used for morphometric characterization of watersheds. One of the Sakarya Basin's sub-basins, the Porsuk Stream Basin, had its morphometric features examined in a GIS setting in the present study. In this case, 23 parameters illustrating the study area's linear, areal, and relief characteristics were analyzed using a 30 m resolution DEM in the ArcGIS 10.8 program. The basin's natural flow patterns and stream network were established by the D8 flow algorithm. The Porsuk Stream, which flows through the provinces of Kütahya and Eskişehir has a basin area of 10.791 km^2 and a basin perimeter of 925.65 km. According to the Strahler method, it is determined that the basin has a 4th order river network and the mean slope is 5.6°. The drainage density (Dd) value of the basin with dendritic drainage type was determined to be

0.12, and the mean bifurcation ratio (Rb) to be 1.78. The study area's calculated drainage density (Dd) value shows a basin with a coarse-grained permeable soil structure. Surface runoff is slow throughout the basin because of the thick vegetation covering the land and the percolation process that surface waters go through before flowing. According to the study, the basin has a form factor value of 0.26 and is narrow and longitudinal in shape. Lower drainage density and lower form factor values result in longer flow collection time in the basin and longer time for tributaries to join the main river. This suggests that there is low probability of flooding and inundation in the basin. The concave hypsometric curve that was generated for the study area indicates that the basin is old stage. However, it is decided that there will be less sediment carried by the main river flow and its tributaries. It is anticipated that soil erosion may occur in the higher regions of the basin and in the sub-basins where there is a high degree of slope and low infiltration, though not across the entire study area. Thus, actions need to be done in sub-basins to stop soil erosion. Specifically, it is important to preserve the land cover and avoid turning the basin's sizable forest areas into agricultural areas. Understanding the hydrological characteristics of watersheds can be achieved through the widely used, practical, and useful techniques of morphmetric analyses carried out in a GIS environment. It is thought that it would be appropriate to prioritize and investigate morphometric analyses at the level of sub-basins in hydrological studies to be carried out, and that such inventory morphometric studies will provide important information that will form the basis for river basin planning and management studies in Turkey. Planning and risk mitigation studies should be carried out by taking into account the morphometric characteristics of the basins, especially in regions where disasters such as floods and floods occur. Morphometric analysis based on GIS in river basins is an effective instrument for understanding the responses of environmental and anthropogenic factors causing climate change, determining changes in precipitation patterns, identifying hydrological and morphological changes in river systems, and understanding ecological processes. In this regard, it is crucial to improve land use practices to reduce erosion and sedimentation processes in the Porsuk Stream Basin, which is an important water source for the study area and nearby cities, to improve vegetation cover, to protect biodiversity and ecosystems, to inform the public about flood or drought conditions and to establish early warning systems in the region. It is of primary significance for the sustainability of the basin that water resources are evaluated on a basin scale and handled together with natural resources, basin management decisions related to erosion processes are applicable, erosion modeling and mapping studies are carried out on a GIS basis by considering the soil types in the basin due to the increase in pressure factors (increasing population, pollution, changes in water quantity and quality, etc.) on the basin due to urban development.

Within the parameters of the development of the study that is being presented, morphometric analyses that can be carried out with greater accuracy using high resolution DEM data that can be acquired from multiple portals can be developed using varying parameters for different geographical areas. The findings obtained will contribute to decision makers in the protection of natural resources such as soil and water, evaluation of processes such as floods, floods, erosion, tectonism and determination of effective basin management strategie.

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EXTENDED ABSTRACT

Morfometrik parametreler herhangi bir havzanın hidrolojik ve morfolojik özelliklerinin anlaşılması amacıyla kullanılan, kantitatif olarak ölçülebilen ampirik eşitliklerle temsil edilmektedir. Özellikle havzaların hidrolojik davranışı, havzanın belirli morfometrik özellikleri tarafından yansıtılmaktadır. Son yıllarda havzaların morfometrik karakterizasyonu için CBS teknolojileri yaygın bir şekilde kullanılmaktadır. Özellikle havza ölçekli etüt ve planlama araştırmalarına başlamadan önce analiz edilen morfometrik parametreler bölgenin topoğrafyası, hidrolojisi ve jeolojisi hakkında önbilgi edinmemizi sağlamaktadır

Çalışma alanı olarak belirlenen Porsuk Çayı Havzası Türkiye'nin İç Anadolu Bölgesinin kuzeybatı kesiminde, Kütahya ilinin doğusu ile Eskişehir il sınırları içerisinde yer almaktadır. Sakarya Nehrinin en uzun kolu olan Porsuk Çayı Doğu-Batı yönünde Eskişehir ovası içerisinde akış göstermektedir. Uzunluğu 357.50 km olan ana akarsu koluna kuzey ve güney yönlerden kolların katıldığı akarsu havzası beslenme alanı 29° 36' ve 31° 57' doğu boylamları ile 38° 43' ve 39° 97' kuzey enlemleri arasında yer almaktadır.

Sunulan çalışmada Porsuk Çayı Havzası'nın morfometrik özellikleri CBS ortamında analiz edilmiştir. Bu kapsamda çalışma alanının çizgisel, alansal ve rölyef özelliklerini gösteren 23 adet parametre 30 x 30 m çözünürlüklü SYM kullanılarak ArcGIS 10.8 programında incelenmiştir. Hidrolojik havza analizi Jenson ve Domingue (1988) tarafından geliştirilen sekiz ana yönlü bir akım modeli olarak tanımlanan D8 yöntemi ile gerçekleştirilmiştir. Havzadaki doğal akarsu akış yönleri ve akarsu ağı çıkarılmıştır. Strahler (1964) yaklaşımına göre ise akarsu dizinleri, dizin sayıları ve akarsu uzunlukları belirlenmiştir. Eskişehir ve Kütahya il sınırları içerisinde kalan Porsuk Çayı havza alanı 10.791 km^2, havza çevresi ise 925.65 km'dir. Strahler yöntemine göre havzanın 4. dereceden bir akarsu ağına sahip olduğu belirlenmiş olup, ortalama eğim miktarı ise 5.6°'dir. Dendritik drenaj tipine sahip havzanın ortalama çatallanma oranı (Rb) 1.78; drenaj yoğunluğu (Dd) değeri ise 0.12 olarak hesaplanmıştır. Çalışma alanı için hesaplanan drenaj yoğunluğu (Dd) değeri; kaba taneli geçirgen zemin yapısına sahip bir havzaya işaret etmektedir. Arazinin yoğun bitki örtüsü ile kaplı olması ve yüzey sularının akışa geçmeden önce süzülmeye uğraması nedeniyle havza genelinde yavaş bir yüzeysel akışın varlığı söz konusudur. Çalışmada 0.26 olarak hesaplanmış olan form faktörü değeri ile havza şeklinin dar ve uzunlamasına bir formda olduğu tespit edilmiştir. Düşük drenaj yoğunluğu ve düşük form faktörü değerleri ile havzada akım toplanma süresi ve yan kolların ana akarsuya katılma süresi daha uzundur. Bu durum havzada sel ve taşkın yaşanma potansiyelinin düşük olduğuna işaret etmektedir. Havza için oluşturulan hipsometrik eğrinin içbükey olması nedeniyle topoğrafyanın yaşlı olduğu saptanmıştır. Bununla birlikte ana akarsu akımının ve akarsu kollarında taşınan sediment miktarının ise düşük olacağı belirlenmiştir. Çalışma alanı genelinde olmasada havzanın yüksek kesimleri ile eğim miktarının yüksek, süzülmenin düşük olduğu alt havzalarda ise toprak erozyonu ihtimalinin olabileceği öngörülmüştür. Dolayısıyla alt havzalarda toprak erozyonunu önlemeye yönelik tedbirler alınmalıdır. Özellikle havzada geniş yer kaplayan orman alanları, tarım alanlarına dönüştürülmemeli, arazi örtüsü korunmalıdır.

CBS ortamında gerçekleştirilen morfometrik analizlerin, havzaların hidrolojik özelliklerinin anlaşılması açısından oldukça yaygın kullanılan, yardımcı ve uygulanabilir teknikler olduğu görülmektedir. Gerçekleştirilecek hidrolojik çalışmalarda morfometrik analizlerin alt havzalar düzeyinde önceliklendirilerek araştırılmasının uygun olacağı, bu tür envanter niteliği taşıyan morfometri çalışmalarının Türkiye'deki nehir havza planlama ve yönetim çalışmalarına altlık oluşturacak önemli bilgiler sağlayacağı düşünülmektedir. Özellikle sel, taşkın gibi afetlerin görüldüğü bölgelerde havzaların morfometrik özellikleri dikkate alınarak planlama ve risk azaltma çalışmaları gerçekleştirilmelidir. Nehir havzalarında CBS tabanlı gerçekleştirilen morfometri analizi iklim değişikliğine neden olan çevresel ve antropojenik faktörlerin tepkilerini anlamak, yağış modellerindeki değişimlerin belirlenmesi, akarsu sistemlerindeki hidrolojik ve morfolojik değişimlerin tespiti ile ekolojik süreçlerin anlaşılması için kullanılan etkili araçlardır. Bu kapsamda çalışma alanı ve yakın çevresindeki kentler için önemli bir su kaynağı olan Porsuk Nehri havzasında erozyon ve sedimantasyon süreçlerinin azaltılması için arazi kullanım uygulamalarının geliştirilmesi, bitki örtüsünün iyileştirilmesi, biyoçeşitlilik ve ekosistemin korunması, halkın sel taşkın veya kuraklık koşulları hakkında bilgilendirilmesi ve bölgede erken uyarı sistemlerinin oluşturulması oldukça önemlidir. Kentsel gelişime bağlı olarak havza üzerindeki baskı unsurlarının (artan nüfus, kirlilik, su miktar ve kalitesindeki değişimler vb.) artması nedeniyle su kaynaklarının havza ölçekli değerlendirilerek doğal kaynaklar ile birlikte ele alınması, erozyon süreçleriyle ilgili havza yönetim kararlarının uygulanabilir olması, erozyon modelleme ve haritalama çalışmalarının havzadaki toprak türleri dikkate alınarak CBS tabanlı yapılması, havza sürdürülebilirliği açısından birincil derecede önemlidir.

Sunulan çalışmanın geliştirilmesi kapsamında; çeşitli portallardan temin edilecek yüksek çözünürlüğe sahip SYM verileri kullanılarak daha yüksek hassasiyetle gerçekleştirilecek morfometrik analizler, farklı bölgeler için amaca yönelik farklı parametreler kullanılarak geliştirilebilir. Elde edilen bulgular toprak, su gibi doğal kaynakların korunması, sel, taşkın, erozyon, tektonizma gibi süreçlerin değerlendirilmesi ile etkin havza yönetim stratejilerinin belirlenmesinde karar vericilere katkıda bulunacaktır.

Ek bilgiler

Çıkar çatışması bilgisi: Herhangi bir çıkar çatışması yoktur.
Destek bilgisi: Araştırma kapsamında herhangi bir kurumdan veya kişiden destek alınmamıştır.
Etik onay bilgisi: Çalışma için etik onay gerekmemektedir.
Katkı oranı bilgisi: Makale tek yazarlı olup tüm çalışma sorumlu yazar tarafından yürütülmüştür.